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The first comprehensive data on the distribution of reptiles within the Southern Bug eco-corridor, Ukraine

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Abstract

This study provides distribution data for 12 species of reptiles in the Southern Bug eco-corridor located within the steppe zone, Mykolaiv Oblast (province), Ukraine. We compiled 935 records from published literature (324), from public databases (68), and from 12 field surveys we made in 2016–2020 (543). All records were mapped on to a grid of 10×10 km, representing the 294 cells of the studied area. We present new distributional data for *Podarcis tauricus*. For all the other species, our records add new localities that fall within areas where these reptiles were previously reported. Species richness and Shannon's H' index show that herpetofauna diversity was higher in the areas along the Southern Bug River. The maximum number of records within a single cell was 118 (for 10 species) in this oblast. Also the high number of identified reptile chorotypes (nine) within the Mykolaiv Oblast revealed that southern Ukraine is an important zoogeographical territory in Europe. These data provide the basis for future biogeographical and ecological studies and conservation priorities.

Key Words

Europe, mapping, Mykolaiv Oblast, occurrence, Reptilia, zoogeography

Introduction

Reliable maps that depict the historical and current distribution of species are an important component in conservation-related research (Sillero et al. 2014). As many reptile species' populations are declining on a global level (Wake and Vredenburg 2008; Sinervo et al. 2010; Böhme et al. 2013), their conservation is a research priority (Jetz et al. 2011; Sillero et al. 2014). Ukraine, especially in the southern lowland parts, is one of the least studied countries in Europe in terms of the distribution of amphibians and reptiles. A total of 26 species were recorded within Ukraine (including the Crimean Peninsula). Out of these, 21 species are native (Kurylenko and Verves 1999) and at least five are introduced or invasive (Darevsky and Szczerbak 1968; Darevsky 2006; Duz et al. 2012; Matvyeyev et al. 2013; Kurtyak and Kurtyak 2013; Krasylenko and Kukushkin 2017). Most of the herpetological research in Ukraine dates back to the Soviet Era (Yablokov 1976; Tarashchuk 1959; Bannikov et al. 1971). The country has less species distribution data compared to similar European areas (Sillero et al. 2014), which is typical of countries of the former USSR (see Zizka et al. 2020). The lowest diversity of reptile species has previously been observed in the zone of mixed and broad-leaved forests, and the greatest – in the steppe and forest-steppe (Tarashchuk 1959).

The Southern Bug River eco-corridor of the steppe zone is located in the south of Ukraine, Mykolaiv Oblast (Province) and encompasses an area of approx. 14,778 km^2 (Fig. 1). This oblast is situated between the Republic of Moldova, and the Danube Delta and the Dnipro

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Figure 1. The study area (Mykolaiv Oblast, Ukraine) indicating geographic areas and places mentioned in the text. Yellow-tan marks the Southern Bug eco-corridor in the steppe zone.

and Dniester Rivers (which are significant biogeographic barriers) and contains the connecting habitat between the eastern Carpathian (Wallachian Plain) and the European steppe areas (Great European Plain; Kostyushin et al. 2007). Herpetologically, it is one of the least known territories in Europe (Kotenko 2006; Sillero et al. 2014). There are numerous conservation areas in the oblast but the most relevant protected area is the Buzk's Gard National Nature Park. In this national park the most ancient geological form in Ukraine (the Ukrainian crystalline shield) comes to the surface (rocky outcrops, slopes, floodplains). These unique ecosystems include rare, endemic and relict species of plants and animals (Didukh 2009; Akimov 2009; Kuzemko et al. 2020).

The Southern Bug River is also valuable for local herpetofauna species, most of which are protected at a national or international level (Akimov 2009; IUCN 2020). Based on published data, 12 species of reptiles are known from the Mykolaiv Oblast and most of them are distributed within the Southern Bug eco-corridor (Tarashchuk 2007). Although the Southern Bug is the only large river in Ukraine whose course is completely within the country, data on the reptile distribution along the river is very limited (Szczerbak 1993; Kurylenko and Verves 1999; Tarashchuk 2007). In this paper, we report on the first comprehensive study on the distribution of reptiles in this area.

Material and methods

The Southern Bug eco-corridor in the steppe zone begins from the northern part of the Mykolaiv Oblast to the Black Sea. The eco-corridor includes the valley of the Southern Bug River and land areas on both sides of the river (Fig. 1). We compiled a set of location data and created distribution maps for species based on three sources: (1) our own data; (2) published data (Yablokov 1976; Tsvelyh 1981; Szczerbak 1993; Kotenko 2000; Dotsenko and Radchenko 2005; Bilyakov and Tarashchyuk 2008; Dovzhenko 2013; Nekrasova 2013; Sillero et al. 2014; Marushchak et al. 2018; Redinov 2018; Suriadna et al. 2018; Mykytynets et al. 2019; Nekrasova et al. 2019; Voblenko et al. 2019); and (3) public databases (UkrBIN,

http://www.ukrbin.com/; GBIF, http://www.gbif.org; iNaturalist, http://www.inaturalist.org). From the public databases we used only records with photos that allowed species identification. We identified species based on Arnold and Ovenden (2002) and followed the taxonomy of Speybroeck et al. (2020).

We obtained data from our own fieldwork performed in the years 2016–2020 (12 expeditions from 3 to 7 days) from April to September throughout the Southern Bug eco-corridor in the steppe zone and some other territories in the Mykolaiv Oblast. Field work was conducted throughout the day (8–10 hours of active field work) whenever weather conditions were seemingly optimal for surveying as many species as possible. Field surveys were primarily based on different selected transects of various lengths or by targeted species searches, covering all types of habitats. Most transects were only visited once. We employed the line transect method, recorded and identified all reptiles found roughly 5 m on both sides of the pathway (Lovich et al. 2012; McDiarmid et al. 2012). We collected data with dipnetting, netting, trawling of water bodies, stone-flipping and other refugia searches, and visual searching. Observations were documented with digital photographs of individuals when possible and surrounding habitats. Captured animals were released at the capture site. Also, we surveyed animals killed by people or vehicular traffic. We recorded coordinates and altitude for all observations using hand-held GPS units.

Published data with unspecified coordinates that could not be georeferenced to an actual locality were not included in this research. Occurrences without geographic coordinates were manually georeferenced to the finest scale possible using the information provided by the source and Google Earth (https://earth.google.com/). The accuracy of published localities was within 5 km, except the data from Sillero et al. (2014) which was within 10–50 km. Although we focus on the Southern Bug eco-corridor in the steppe zone of Ukraine, we also included reptile records from all over Mykolaiv Oblast (own and published data).

We created all maps using QGIS Desktop 3.10.8 software (2019) (using the coordinate system UTM, zone 36N). Two types of maps were created: with precise GPS locations of the records and with the general distribution of species on the grid. We used a Universal Transverse Mercator (UTM) grid of 10×10 km size. The grid for the whole Mykolaiv Oblast comprises 294 cells. We used original and literature data (only if exact coordinates were available) for altitude analysis. For literature data, the altitude was estimated using Google Earth. Chorotypes were identified according to the classification of Vigna Taglianti et al. (1999) with some adjustments (Table 1). To assess the diversity of reptiles in the Mykolaiv Oblast, we calculated species richness, namely Shannon's diversity index (H'). Species richness refers to the total number of species recorded per grid cell. Shannon's index was calculated in R 4.0.2 (R Core Team 2020) using the "vegan" package (Oksanen et al. 2019).

Results and discussion

Species records

The compiled checklist of reptile species occurring in Mykolaiv Oblast includes 12 species of four families, and it is based on 935 records (543 original data, 324 published, 68 from public databases; Table 1). The list of recorded species with names of localities and UTM codes is presented in the Suppl. material 1. The original distribution data (coordinates) are available on request. Merging multiple observations of the same species within the same grid cell resulted in 282 species-cell observations remaining. Some species frequently represented by numerous records per grid cell showed higher values in the percentage of observations in comparison to the percentage of occupied grid cells (e.g. *Lacerta viridis*; Table 1), or vice versa, occupied more grid cells than the general overall trend would predict, judging by their number of observations (e.g. *Emys orbicularis*; Table 1). This is likely to be due to both habitat specificity as well as relative ease of observation; other types of biased sampling (seasonal and behavioural effects) may add to this imbalance.

The western and eastern parts of the Mykolaiv Oblast have visible gaps in the mapping (Fig. 2). Most data

Table 1. Reptiles with chorotype classification of the Mykolaiv Oblast, Ukraine. Overview of available records per species, including number of records (Rn), percent of records from total dataset (R%; n = 935), number of occupied grid cells (Cn; 10×10 km) and percent of occupied grid cells from total number of grid cells (C%; n = 294).

Species	Rn	R%	Cn	C%	Chorotype
Emys orbicularis	95	10.3	41	13.8	Turano-European-Mediterranean
Eremias arguta	26	2.7	16	5.4	Turano-European
Lacerta agilis	50	5.2	29	9.8	Euro-Siberian
Lacerta viridis	323	34.6	32	10.8	Southern-European
Podarcis tauricus	26	2.6	9	3	Eastern-Mediterranean
Natrix natrix	39	4.2	24	8.1	Central Asiatic- European-Mediterranean
Natrix tessellata	55	6	32	10.8	Turano-European
Coronella austriaca	7	0.7	7	2.3	European
Dolichophis caspius	171	18.2	54	18.3	Eastern-Mediterranean
Elaphe sauromates	34	3.6	23	7.8	Turano-Mediterranean
Zamenis longissimus	23	2.3	7	2.3	Southern-European
Vipera renardi	86	9.3	8	2.7	Central Asiatic-European
Total	935	99.9	282	95.1	9

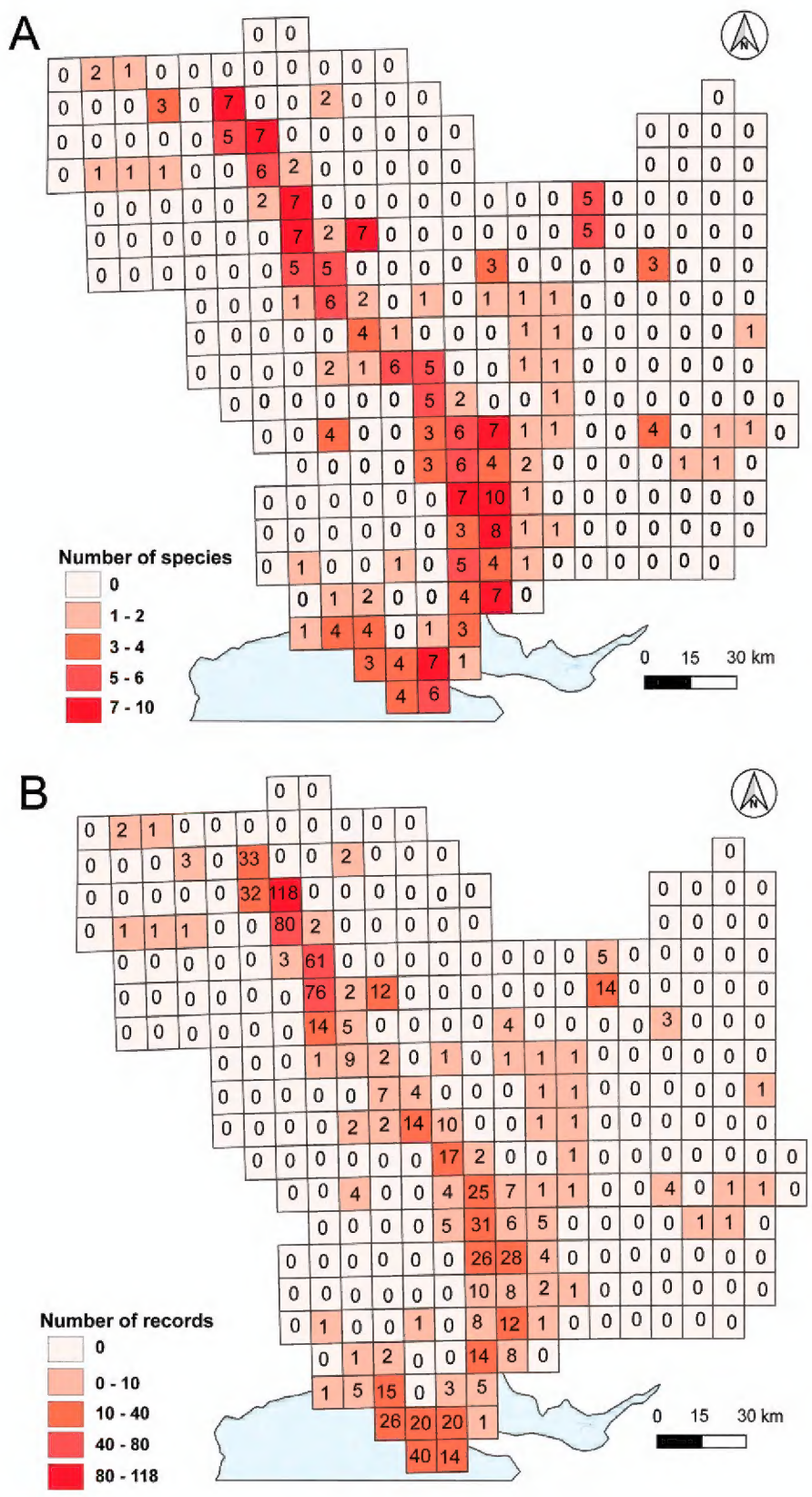

Figure 2. Number of herpetofaunal species (**A**), number of records (**B**) and Shannon's diversity index (**C**) within a 10 km grid of the Mykolaiv Oblast.

are concentrated along the Southern Bug River which served as the working base for most of the field trips. The frequency distribution of specific grid occupancy rates (number of grid cells by number of herpetological species and records) was higher in the north-central part of the oblast and around the city of Mykolaiv (Fig. 2). The highest number of species within a single cell was ten and the maximum number of records was 118 (for seven species) in the northern part of the oblast. The largest number of species and records were both within the Southern Bug eco-corridor, also reflected by the Shannon's H' index (Fig. 2).

The Mykolaiv Oblast is a lowland area that gradually decreases from the north to the south in the Black Sea region. The elevations within the landscape range from -3 to 255 m a.s.l. The observed herpetofauna occurred from -2 to 126 m a. s. l. (Fig. 3). *Lacerta viridis* was the species with the highest recorded elevation with the majority of records at 0–98 m a.s.l. *Elaphe sauromates* and *Dolichophis caspius* had the lowest elevation (-2 m) that were found on the Kinburn Spit (the lowest area in the oblast).

Our analysis distinguished nine chorotypes of reptiles in the studied area: Turano-Europeo-Mediterranean, Centralasiatic-European, Euro-Siberian, Southern-European, Eastern-Mediterranean, Centralasiatic-Europeo-Mediterranean, Turano-European, European, Turano-Mediterranean (sensu Vigna Taglianti et al. 1999; Table 1). *Lacerta viridis* and *Zamenis longissimus* belong to the Southern-European chorotype. *Podarcis tauricus* and *D. caspius* – the Eastern-Mediterranean chorotype, and *Eremias arguta* and *Natrix tessellata* are the Turano-European representatives. The remaining chorotypes are represented by a single species. We include further details on our observations and comment on the relevant literature in the following species accounts.

Emydidae

Emys orbicularis Linnaeus, 1758

Numbers of records. 95 (10.3% of the data).

Number of grid cells. 41 (13.8% of the entire grid; Table 1; Figs 4, 8A).

Comments. Widely distributed in the steppe zone of Ukraine, most abundant in the deltas of big rivers (Kotenko 2000). Most records are concentrated along the Southern Bug River valley. Known from the territory of the Buzk's Gard National Nature Park (near Migia, Yuzhnoukrainsk), Kinburn Spit and near the city of Mykolaiv (Kotenko 2000; Dotsenko and Radchenko 2005; Sillero et al. 2014). Isolated observations from different parts of the Mykolaiv Oblast (Kotenko 2000; Dotsenko and Radchenko 2005). Although all our records represent new localities, they fall within the areas where these turtles were previously known.

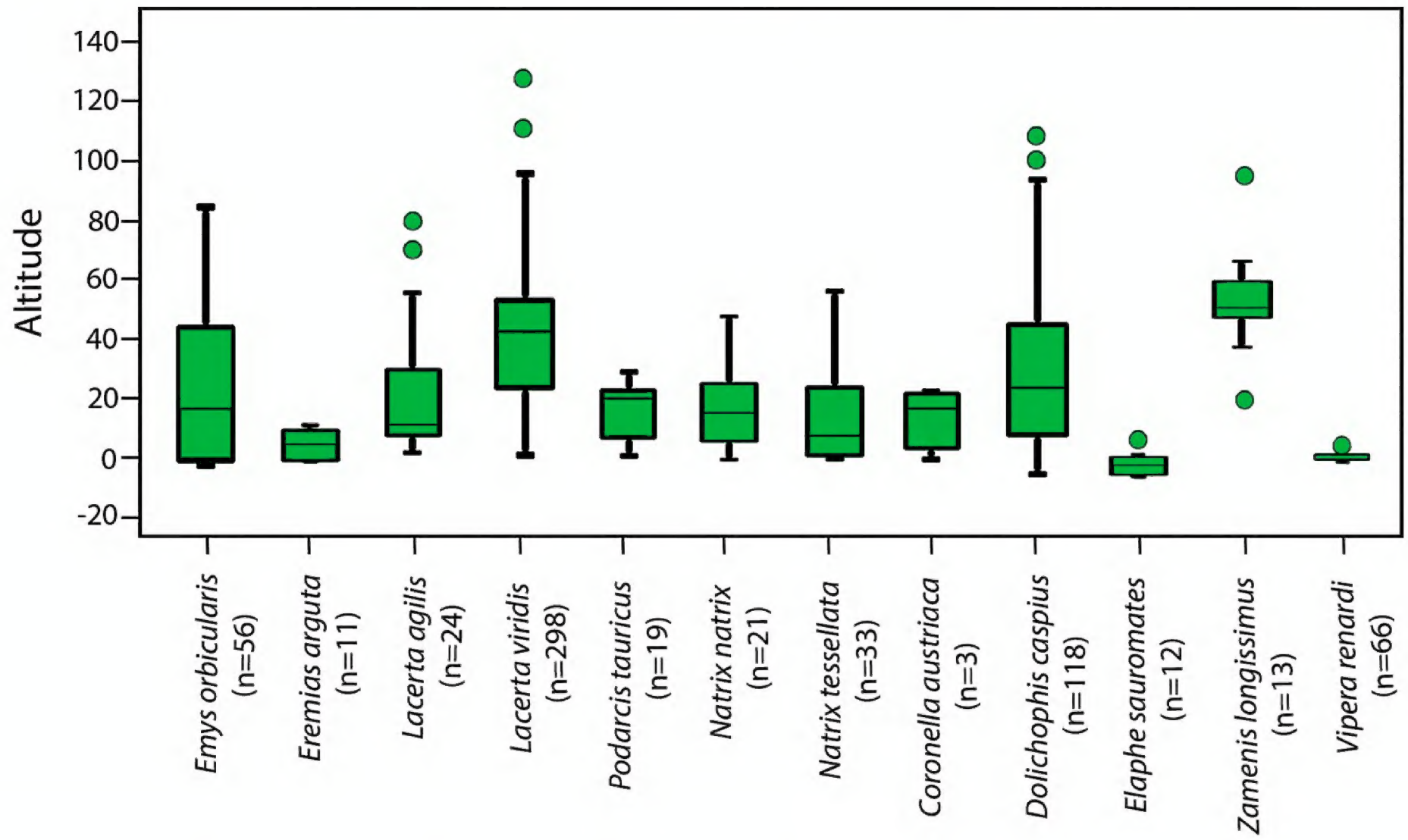

Figure 3. Altitudinal distribution of the reptile species in the Mykolaiv Oblast, Ukraine.

Lacertidae

Eremias arguta (Pallas, 1773)

Numbers of records. 26 (2.7% of the data).

Number of grid cells. 16 (5.4% of the entire grid; Table 1; Figs 4, 8B)

Comments. *Eremias arguta* was reported from the northern part and along the Southern Bug River to the Black Sea coast (Szczerbak 1993; Dotsenko and Radchenko 2005; Tarashchuk 2007; Sillero et al. 2014). We found this species only in four localities: one north of Mykolaiv city near the Balovne Village, and three near the estuary Galitsynove Village and Kinburn Spit. Historic records from the northern part of the Mykolaiv Oblast are particularly interesting because this species has practically disappeared from central Ukraine. We checked these points (Oniscoves, Sirovo, Rybakivka, Oleksandrivka and Voznesensk villages; Szczerbak 1993; Dotsenko and Radchenko 2005), but did not find the species there. In Ukraine, the species' range is limited to the steppe and, partially, the forest-steppe zones. It inhabits biotopes with sandy and sandy-shells soils with thin psammophilous steppe and halophilous herbaceous vegetation (Szczerbak 1993). As forests grow and the crowns of the trees close, *E. arguta* gradually disappears. An increase of the projective cover of herbaceous vegetation leads to the same result (Polynova and Mishustin 2020). Strict requirements for substrate and light lead to a mosaic-strip character of the subspecies' distribution (Kotenko 1986). We hypothesize that we did not find the species in the north because previously suitable habitats have been planted with forests in the 1990s (Tkach 2012).

Lacerta agilis Linnaeus, 1758

Number of record. 50 (5.2% of the data).

Number of grid cells. 29 (9.8% of the entire grid; Table 1; Figs 4, 8C).

Comments. This species is rare in southern Ukraine, although common in the rest of the country (Tarashchuk 1959; Yablokov et al. 1976). The Sand lizard has mosaic distribution in the Mykolaiv Oblast (Dotsenko and Radchenko 2005; Nekrasova 2013; Sillero et al. 2014), near the borders of the eco-corridor. Sightings are relatively uncommon and there are significant gaps in the distribution in parts of the oblast. Observations are mainly located in the centre of the oblast, which might be related to a relatively higher sampling effort in that area, as well as a locally higher availability of suitable habitat. Most of the individuals have been observed near fields, gardens or pastures.

Lacerta viridis Laurenti, 1768

Number of records. 323 (34.6% of the data).

Number of grid cells. 32 (10.8% of the entire grid; Table 1; Figs 5, 8D, E).

Comments. This species showed higher values in the percentage of observations than the number of observa-

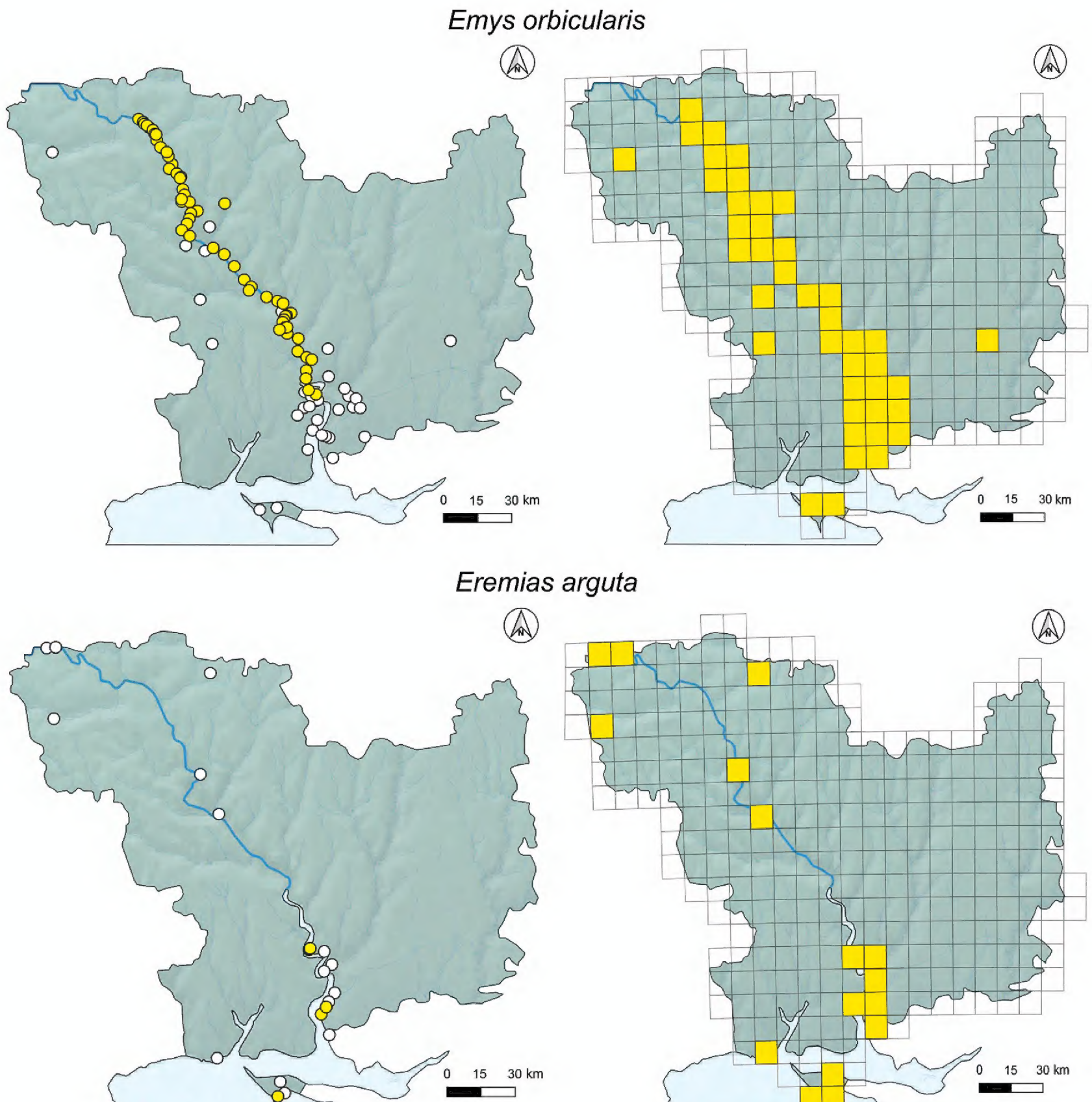

Figure 4. Distribution of (species) within the Mykolaiv Oblast (Ukraine), based on localities (left; white circles – literature and public database data, yellow circles – authors' data) and 10 km UTM grid (right; yellow squares – species recorded).

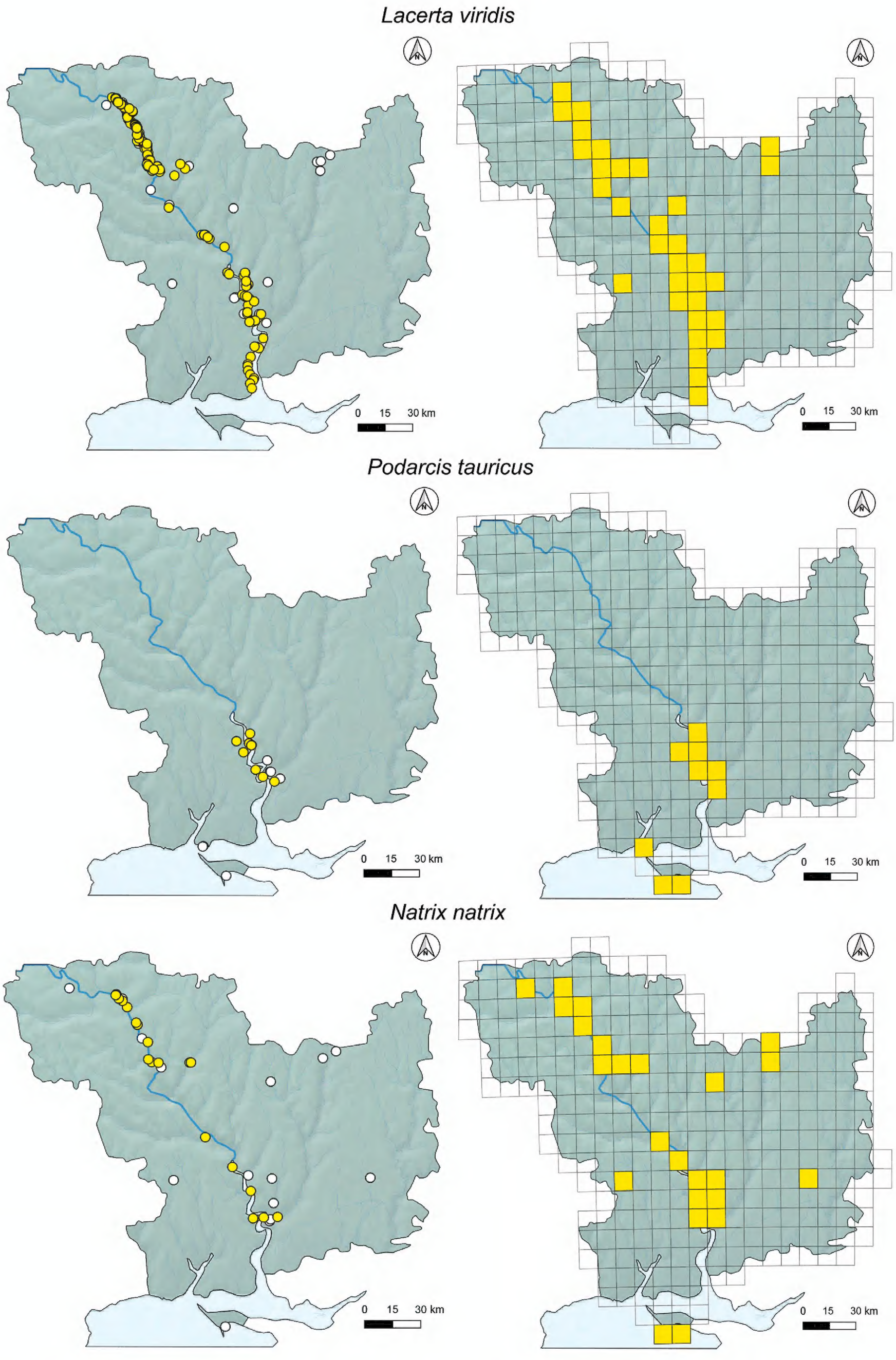

Figure 5. Distribution of (species) within the Mykolaiv Oblast (Ukraine), based on localities (left; white circles – literature and public database data, yellow circles – authors' data) and 10 km UTM grid (right; yellow squares – species recorded).

tions per grid cell. It is known mainly from the Buzk's Gard National Nature Park and near Mykolaiv (Dotsenko and Radchenko 2005; Sillero et al. 2014; Suriadna et al. 2018; Mykytynets et al. 2019). Some records were made in the Inhul River valley (north-eastern part of the Mykolaiv Oblast; Dotsenko and Radchenko 2005; Nekrasova 2013). Most of our own records were along the valley of the Southern Bug River (from Pervomaisk to the estuary). The highest number of records were from Buzk's Gard National Nature Park (Fig. 10D). In contrast to the other lizards, we found this species often and in high numbers.

Podarcis tauricus (Pallas, 1814)

Number of records. 26 (2.6% of the data).

Number of grid cells. Nine (3% of the entire grid; Table 1; Figs 5, 8F).

New localities. Near the villages Sebine (47.15°N, 31.85°E), Novohryhorivka (47.11°N, 31.76°E), Kamyana Balka (47.06°N, 31.81°E) and Trihati (47.10°N, 31.87°E; Fig. 10C)

Comments. Density of this species seems relatively low in this oblast (Dotsenko and Radchenko 2005). In Ukraine the northern border of the range of this species is south of the city of Mykolaiv (Böhme et al. 2009). The species was reported from near Ochakov, on the Kinburn Spit and within Mykolaiv (Dotsenko and Radchenko 2005; Dovzhenko 2013). Our observations were made 60–80 km north of the previous reports. Two records were from the left bank of the South Bug River, versus 16 from the right (Fig. 10C).

Natricidae

Natrix natrix (Linnaeus, 1758)

Number of records. 39 (4.2% of the data).

Number of grid cells. 24 (8.1% of the entire grid; Table 1; Figs 5, 9A).

Comments. This species is fairly frequently observed and distributed in different parts of the oblast (Dotsenko and Radchenko 2005; Nekrasova 2013; Sillero et al. 2014). We found most individuals in the Oleksandrivske Reservoir and in the floodplains near Mykolaiv. Its range is similar to that of *N. tessellata* and these species can occur sympatrically. The records of *N. natrix* were fewer than those of *N. tessellata* presumably because there are not a lot of suitable habitats for this species in this oblast.

Natrix tessellata Laurenti, 1768

Number of records. 55 (6% of the data).

Number of grid cells. 32 (10.8% of the entire grid; Table 1; Figs 6, 9B).

Comments. This species is common in Mykolaiv (Kotenko et al. 2011), but has a scattered distribution, found mostly around the Southern Bug River valley (Dotsenko and Radchenko 2005; Nekrasova 2013; Sillero et al. 2014). We also observed this species along the entire valley of the Southern Bug River.

Colubridae

Coronella austriaca Laurenti, 1768

Number of records. Seven (0.7% of the data).

Number of grid cells. Seven (2.3% of the entire grid; Table 1; Figs 6, 9C).

Comments. This species is rare in the Mykolaiv Oblast. It was recently recorded from Kinburn Spit (Mykytynets et al. 2019). We confirmed the finding of an individual near Mykolaiv (Zaichevsk village) reported in iNaturalist (https://www.inaturalist.org/observations/14612688). We found the snake in a steppe area with small shrubs (Fig. 10A). The data of Sillero et al. (2014) (36TUT3 and 36TVS1) reflect historic records of populations that are likely no longer present. In 1979, this species was recorded on rocky banks of the Southern Bug River in the areas of the South Ukrainian Nuclear Power Plant (Tsvelyh 1981), but recent surveys (Kotenko et al. 2008, this study) have failed to detect it despite intensive investigation.

Dolichophis caspius (Gmelin, 1789)

Number of records. 171 (18% of the data).

Number of grid cells. 54 (18.3% of the entire grid; Table 1; Figs 6, 9D).

Comments. This is the most common snake with a high number of observations per grid cell (Table 1). This species is known throughout the Mykolaiv Oblast (Dotsenko and Radchenko 2005; Tarashchuk 2007; Bilyakov and Tarashchyuk 2008; Nekrasova 2013; Sillero et al. 2014; Marushchak et al. 2018; Redinov 2018; Mykytynets et al. 2019; Nekrasova et al. 2019; Voblenko et al. 2019). We found multiple individuals within the Southern Bug eco-corridor in the steppe zone and a single one near the village of Snihurivka. Most records were from Buzk's Gard National Nature Park (Fig. 10D). The known distribution for this species shows a broad occurrence throughout the oblast, albeit with significant gaps, most likely due to lack of sampling. We found this species more often than other snakes in this oblast.

Elaphe sauromates (Pallas, 1814)

Number of records. 34 (3.6% of the data).

Number of grid cells. 23 (7.8% of the entire grid; Table 1; Figs 7, 9E).

Comments. Records of this species are scattered; it is recorded infrequently and it is unclear to what extent this is due to its secretive habits, actual rareness or other factors. The species has mosaic distribution in the studied area and is often found in the Inhul River valley and in the eco-corridor near Mykolaiv (Tarashchuk 2007; Bilyakov and Tarashchyuk 2008; Sillero et al. 2014; Redinov 2018; Jablonski et al. 2019; Mykytynets et al. 2019; Voblenko et al. 2019). We have only two records of this species near the villages of Zaichevsk and Peresadivka.

Zamenis longissimus (Laurenti, 1768)

Number of records. 23 (2.3% of the data).

Number of grid cells. Seven (2.3% of the entire grid; Table 1; Figs 7, 9F).

Comments. In Ukraine, *Z. longissimus* reaches the eastern border of the European part of its range (Böhme 1993). Populations are concentrated mainly in the western part of the country; most individuals were recorded from Transcarpathia (Szczerbak and Szczerban' 1980; Darevsky and Orlov 1988). In the Middle Dniester region it is extremely rare or has completely disappeared (Dotsenko et al. 2013); there is also a stable population quite remote from the main part of the range in the valley of the Southern Bug River (Dotsenko and Radchenko 2005; Bilyakov and Tarashchyuk 2008; Dotsenko et al. 2013; Sillero et al. 2014; Suriadna et al. 2018; Voblenko et al. 2019). Records for the Mykolaiv Oblast seem distributed rather sparsely. Our records were from Mygiya to the village of Semenivka. Also, in September 2020, two adults were found near Yuzhnoukrainsk. The population is distributed in warm forested areas with hilly or rocky habitats with proper insolation and varied vegetation (Fig. 10B). A population was reported from the Trykratskyi Forest (UkrBIN ID #113093).

Viperidae

Vipera renardi (Christoph, 1861)

Number of records. 86 (9.3% of the data).

Number of grid cells. eight (2.7% of the entire grid; Table 1; Fig. 7).

Comments. In 2016, we confirmed literature reports from Kinburn Spit (Dotsenko and Radchenko 2005; Kolomiets et al. 2008). In the following years, this species was repeatedly reported for this area (Mizsei et al. 2018; Redinov 2018; Mykytynets et al., 2019). Despite Sillero et al. (2014) reporting the species from the estuary of the Southern Bug River and Mykolaiv, the species' presence there remains questionable, due to the lack of recent records (see Baybuz et al. 2011; Mizsei et al. 2018).

Species diversity and biogeography

Our study presents results based on the most complete database of reptile occurrences in the Southern Bug eco-corridor to date, including data on all species currently known to occur in this oblast. Our findings corroborate the presence of most species reported in the past. Unfortunately, the Southern Bug eco-corridor in the steppe zone still lacks detailed and comprehensive data on the distribution of the local herpetofauna. Previous published studies were focused on the territory of the Buzk's Gard National Nature Park (Bilyakov and Tarashchyuk 2008; Suriadna et al. 2018; Nekrasova et al. 2019), Kinburn Spit (Redinov 2018; Voblenko et al. 2019), the vicinity of Mykolaiv (Dotsenko and Radchenko 2005; Dovzhenko 2013), or the data were presented without exact location (Tarashchuk 1959, 2007; Strugren and Rădulescu 1961; Kurylenko and Verves 1999; Kostyushin et al. 2007). Although we added valuable information, further surveys are needed.

The studied oblast is inhabited by reptiles that are locally abundant (e.g., *L. viridis*, *D. caspius*), or rare (e.g., *C. austriaca*, V. *renardi*). Undoubtedly, *L. viridis* and *D. caspius* in Ukraine have uneven distribution ranges, while *V. renardi* and especially *C. austriaca* are much more widespread; but probably with low densities and observed rarely. The most abundant species is *L. viridis* with the highest number of sightings, probably because it is an easily detectable species (Table 1). Still, this species is rare in Ukraine and the density of many of its populations is insufficiently studied (Kotenko and Sytnik 2009).

We added new locality data for *P. tauricus* that expands its known range (Fig. 5). This species is distributed almost all over Crimea (Kotenko and Kukushkin 2010), while in the south of the steppe zone of Ukraine, it is characterised by a mosaic distribution (most of the records are from the Odessa and Kherson regions; Dotsenko and Radchenko 2005; Kotenko 2007; Dovzhenko 2013). The northernmost populations of *P. tauricus* were so far recorded in the vicinity of Mykolaiv (Dovzhenko 2013). We, however, found new populations further north during our investigations.

The data for *C. austriaca* were outdated in the studied area but we confirmed that this species is present in Mykolaiv Oblast (Table 1; Figs 6, 9C). The rarity of records for *C. austriaca* might be a result of the species' low detectability and overall secretive lifestyle.

Given that the Mykolaiv Oblast is situated in the lowlands, the majority of the records of reptiles were from low elevations (see species list and Fig. 3). Our study reports the lower elevation limit for most of the observed species.

Our overall data, however, showed notably higher diversity in the Southern Bug eco-corridor (including numbers of species and records) compared to other areas in Mykolaiv Oblast (Fig. 2). This could be explained by higher habitat diversity (Kostyushin et al. 2007; Kuzemko et al. 2020). According to our results, diversity was higher in the northern part of the oblast which was seemingly less impacted by human activities and includes

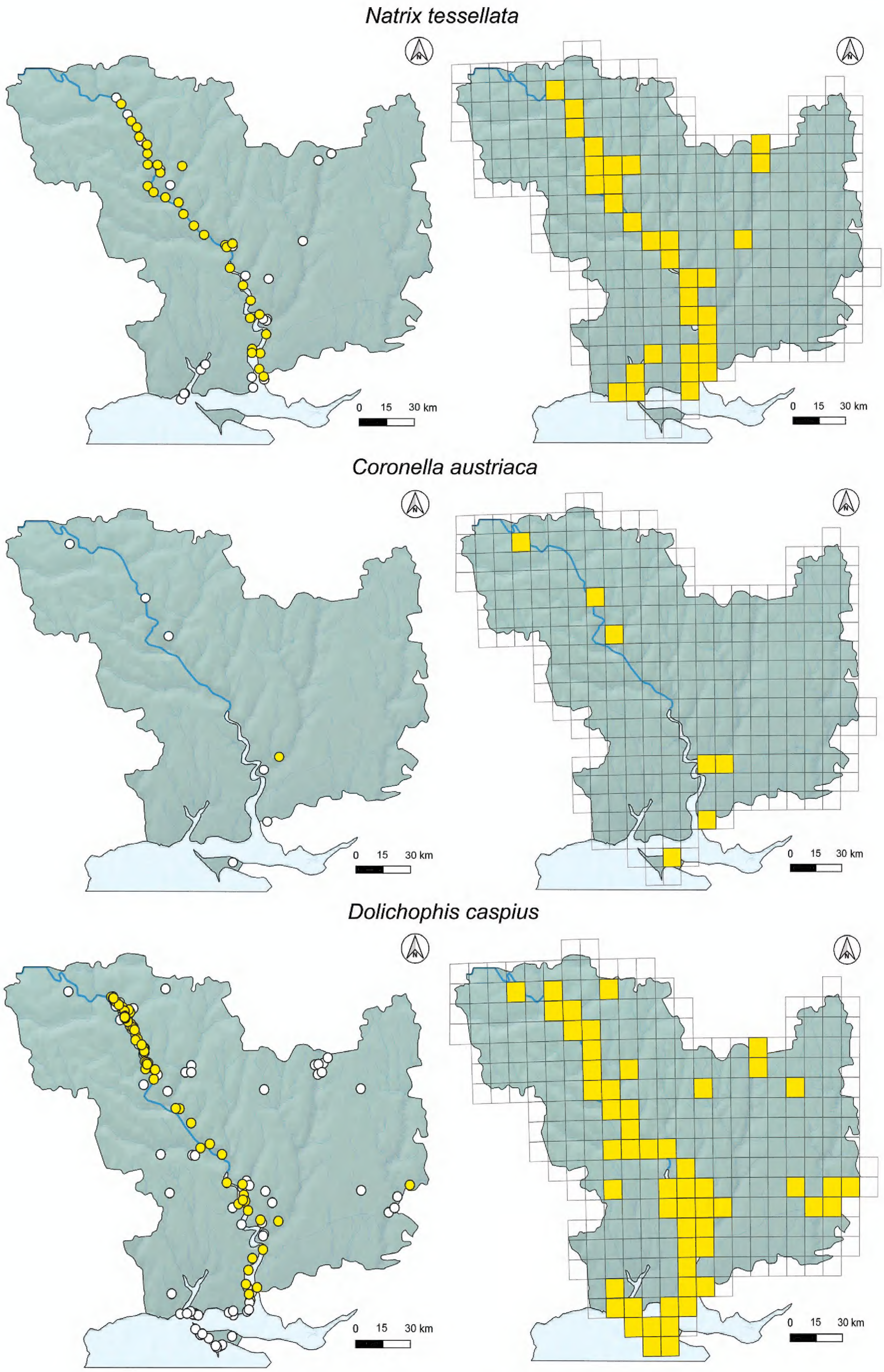

Figure 6. Distribution of (species) within the Mykolaiv Oblast (Ukraine), based on localities (left; white circles – literature and public database data, yellow circles – authors' data) and 10 km UTM grid (right; yellow squares – species recorded).

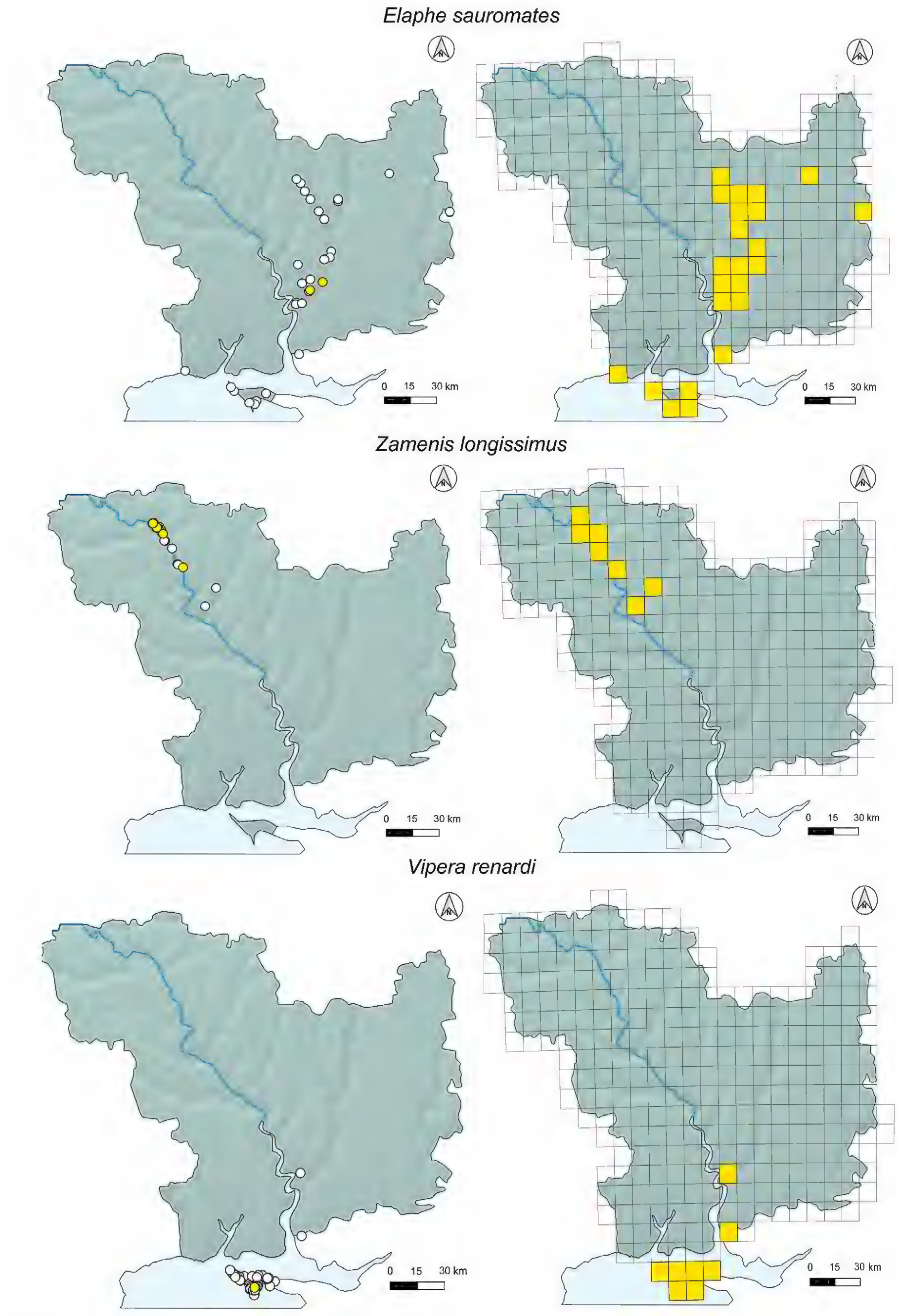

Figure 7. Distribution of (species) within the Mykolaiv Oblast (Ukraine), based on localities (left; white circles – literature and public database data, yellow circles – authors' data) and 10 km UTM grid (right; yellow squares – species recorded).

Figure 8. Representative pictures of species of herpetofauna: **A.** *Emys orbicularis*, juvenile, Hrushivka; **B.** *Eremias arguta*, Balovne; **C.** *Lacerta agilis*, Voznesensk; **D.** *Lacerta viridis*, juvenile, Kuripchyne; **E.** *Lacerta viridis*, male (front) and female, Voznesensk; **F.** *Podarcis tauricus*, Novohryhorivka. Photographs by D. Shyriaieva (**A**), O. Oskyrko (**B, C, D, E, F**).

some protected areas (Fig. 2). On the other hand, in the south, the species diversity was higher in the vicinity of Mykolaiv city than in the northern part and other territories in Mykolaiv Oblast. This can mean synanthropy for many species. The species richness and Shannon's H' index follow a similar pattern, with most species concentrated along the Southern Bug eco-corridor. This can be because most of this area is part of the Buzk's Gard National Nature Park which experiences low anthropogenic impact. This implies that the Southern Bug eco-corridor is a territory of interest for future reptile conservation activities in Ukraine.

The high number of identified reptile chorotypes within the Mykolaiv Oblast indicates that Ukraine is an important territory from a zoogeographical point of view (Table 1). A detailed zoogeographic classification

Figure 9. Representative pictures of species of herpetofauna: **A.** *Natrix natrix*, Migia; **B.** *Natrix tessellata*, Yuzhnoukrainsk; **C.** *Coronella austriaca*, Mykolaiv; **D.** *Dolichophis caspius*, juvenile, Mykolaiv; **E.** *Elaphe sauromates*, valley of the Inhul River; **F.** *Zamenis longissimus*, Migia. Photographs by S. Lehkyy (**A, B**), V. Strenada (**C, D, E, F**).

of the herpetofauna of Ukraine has not been carried out. Zoogeographically, Ukraine belongs to the Euro-Siberian zone of the western Palearctic (Sindaco et al. 2013). Considering Ukraine's location, its herpetofauna contains both European and Asian elements (Charlemagne 1937; Szczerbak 1982, 1988). Also, the high number of different identified reptile's chorotypes, along with data on the phylogeography of particular species, indicates that the Northern Black Sea region was colonised from the neighbouring regions, with which it was closely geographically connected during different epochs of the Late Pleistocene and Holocene, i.e. from Balkans, the Ciscaucasia and the Crimea (e.g. Fritz et al. 2009; Guicking et al. 2009; Musilova et al. 2010; Poyarkov et al. 2014; Zinenko et al. 2015; Marzahn et al. 2016; Psonis et al. 2018; Jablonski et al. 2019a, b). However, the North Black Sea region

Figure 10. Representative habitats for the herpetofauna in the Mykolaiv Oblast: **A.** habitat of *Coronella austriaca* near the village of Zaichevsk; **B.** habitat of *Zamenis longissimus* near the village of Grushivka; **C.** habitat of *Podarcis tauricus* near the village of Trykhaty; **D.** Buzk's Gard National Nature Park. Photographs by V. Strenada (**A**), O. Oskyrko (**B, C, D**).

may also be a potential source of local genetic diversity for at least some reptile species (see Kukushkin et al. 2020; Mahtani-Williams et al. 2020).

Conservation implications

The main threats to reptiles in Europe, according to the IUCN Red List, are agriculture, residential/commercial development, and biological resource use. These threats primarily cause habitat fragmentation and loss (Visconti et al. 2018). The steppe biome, which has undergone an extremely strong anthropogenic transformation in south-western Ukraine, is in a particularly endangered position (see Wesche et al. 2016). Specific threats include a plan by South-Ukraine electric power producing complex (SUEPPC) to raise the level of the Oleksandrivske Reservoir by 20,7 metres to provide a major part of the useful capacity of the water storage for logistics water supply to Mykolaiv Oblast (https://www.sunpp.mk.ua/sites/default/files/documents/zayava_pro_namiri.pdf). This would impact the canyon of the Southern Bug River in between the town of Oleksandrivka, Voznesensk region and the south outskirts of Yuzhnoukrainsk city (including the territory of the Buzk's Gard National Nature Park). This move would flood extensive surfaces of rocky habitats and, therefore, will lead to the destruction of natural biotopes and local animal populations including reptiles. In Mykolaiv Oblast, the increasing level of the Oleksandrivske Reservoir can lead to a significant reduction of the suitable habitats for reptiles and increase the risk of species' local extinction. This will destroy habitats of *L. viridis*, *D. caspius*, and *Z. longissimus*, included in the Red Book of Ukraine (Akimov 2009). Additionally, the local population of *Z. longissimus* is the only one known in the steppe zone of Ukraine (the nearest known present-day sites are located in Transcarpathia and in the vicinity of the Dniester canyon; Bezman-Moseyko 2010; Dotsenko et al. 2013). In 2019, SUEPPC conducted an environmental impact assessment (EIA) for raising the level of the Oleksandrivske reservoir (http://eia.menr.gov.ua/uploads/documents/564/reports/qeWQHoa707.pdf). However, this document contains a lot of shortcomings and does not consider the specifics of protected species.

In addition, significant threats include illegal capture of species for the pet trade (e.g., *L. viridis*) and killing of snakes due to insufficient environmental awareness (Artamonov, 2020 personal observation). These problems are exacerbated by poor enforcement of existing laws, in-

difference of the local government, people's phobias and taboos regarding reptiles, and lack of environmental education among local people. Threats could be diminished by increased environmental education, actions and control of local government, fines for violating the laws.

The results of this study help with conservation activities for the herpetofauna in southern Ukraine, i) expanding existing protected areas, ii) establishing new protected areas, iii) revising development plans taking into consideration nature conservation needs, iv) establishing legislation against illegal trapping and trade of amphibians and reptiles, v) regular monitoring of populations.

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Supplementary material 1

Records of herpetofaunal species with names of localities and 10 km UTM codes (UTM Zone 36N) within the Mykolaiv Oblast, Ukraine

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Data type: Adobe PDF file

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